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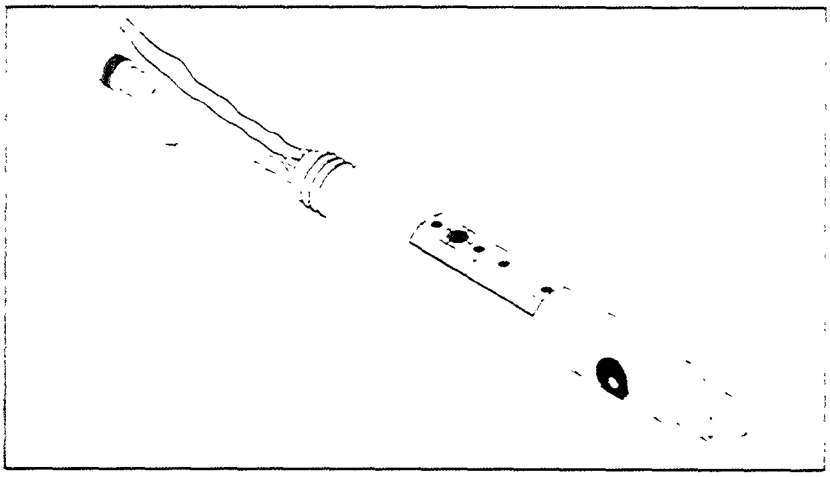
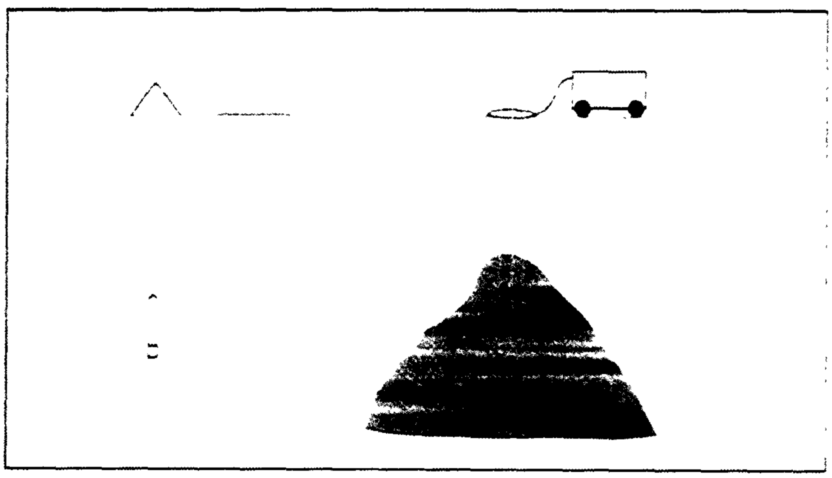
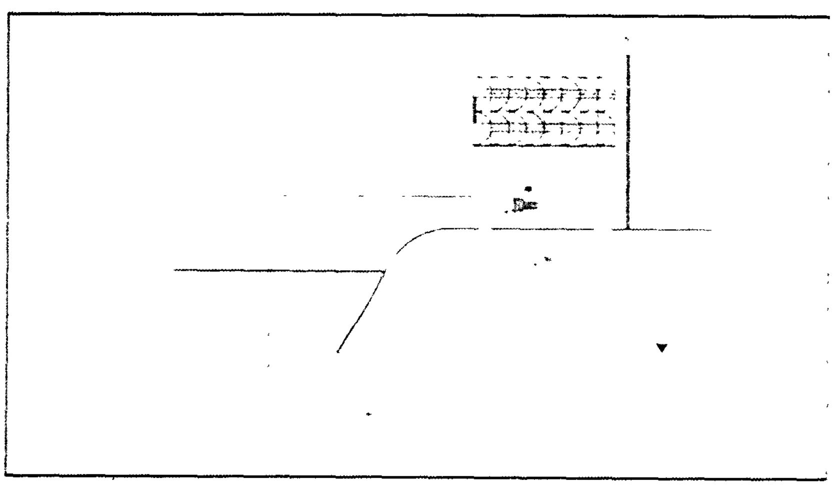
Sensor Technologies Used During Site Remediation Activities - Selected Experiences







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Sensor Technologies Used During Site Remediation Activities – Selected Experiences

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ACRONYMS AND ABBREVIATIONS

1, 2-DCE	1, 2-dichloroethene
2D-Recon	Two-dimensional gradiometer
ASTM	American Society of Testing and Materials
BAAP	Badger Army Ammunition Plant
Bgs	Below ground surface
BRL	Basic relay logic
BTEX	Benzene, toluene, ethyl benzene, and total xylenes
COC	Contaminant of concern
CPU	Central Processing Unit
CPU	Central Processing Unit
Cr-VI	Hexavalent chromium
DA	Data acquisition
DBG	Deterrent Burning Ground
DELCD	Dry electrolytic conductivity detectors
EC	Electrical conductivity
ECD	Electron capture detector
EOL	Electromagnetic offset log
EPA	U.S. Environmental Protection Agency
FID	Flame ionization detector
ft/day	Feet per day
GC	Gas chromatograph
HMI	Human machine interface
HOA	Hand-off-auto
Hz	Hertz
IrriMAX	Vendor-supplied standard calibration model
LED	Light emitting diode
LPZ	Low permeability zones
MFA	Moffett Federal Airfield
MIP	Membrane interface probe
mL/min	Milliliters per minute
mV	Millvolts
NELP	Navy Environmental Leadership Program
NIBW	North Indian Bend Wash
NPDES	National Pollutant Discharge Elimination System
NTS	Nevada Test Site
°C	Degrees Centigrade
Ogden	Ogden Environmental and Energy Services Co., Inc.
OSHA	Occupational safety and health administration
PC	Anywhere (communications software)
PC	Personal computer
PID	Photoionization detector
PLC	Programmable logic controller
PLC	Programmable logic controllers
ppb	Parts per billion
R&D	Research and development

RI	Remedial investigation
SCADA	Supervisory control and data acquisition
SDI	Serial data interface
Sol Lynn	Sol Lynn/Industrial Transformer Superfund
Sprague Road	Sprague Road Ground Water Plume Superfund
SRI	Supplemental remedial investigation
TCE	Trichloroethene
THM	Trihalomethanes
USDA	U.S. Department of Agriculture
UST	Underground storage tank
UV	Ultraviolet light
VC	Vinyl chloride
VECTOR	Variably Emitting Controlled Thermal Output Recorder
VOC	Volatile organic compounds.
WBZ	Water bearing zones
WBZ	Water bearing zones

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1.0 INTRODUCTION

1.1 WHAT ARE SENSORS?

A sensor is a device that produces a discernable response to external stimulus. Some examples of sensors are thermometers, photoelectric cells, pressure transducers, and smoke detectors. Electronic sensors respond to stimulus by producing standardized electrical signals. This enables them to interface with devices that display a readable output or larger systems providing sensory input to a decision-making device. For example, sensors may be used inside a storage tank to supply information on fluid levels to a system controller who would in turn use this information to make decisions on starting or shutting down pumps that fill or drain the tank. Sensors can be used in environmental remediation for the following activities:

- Characterization
- Monitoring
- Automation

When properly applied, sensors can provide long-term benefits for remediation projects by reducing manpower requirements, reducing analytical costs, and generating information that facilitates process optimization.

1.2 PURPOSE OF REPORT

Environmental remediation includes many activities that require measurement and monitoring of parameters such as contaminant concentrations, media characteristics, and systemic parameters. In recent years, there has been an increase in the number and types of sensor technologies used during site remediation. These include technologies that are used for performing real-time and continuous measurements, remote monitoring, remote operation, and system automation.

The U.S. Environmental Protection Agency (EPA) prepared this report to provide an overview of several types of sensor technologies and a summary of selected experiences with using the technologies during site remediation activities. The report highlights the applications, implementation, strengths and limitations, and lessons learned from actual projects that have used one or more sensor technologies as part of an overall site remediation strategy. Appendices one through seven provide case studies for specific sites that have used sensor technologies during site remediation activities.

This report does not provide guidance on the selection of a specific type or vendor of sensor technology; these technologies are most cost-effective under specific environmental, chemical, and physical conditions. Numerous site-specific considerations, such as site geology, soil, and aquifer characteristics, chemical, physical, and biological parameters of affected media, and chemicals of concern, among many others, can impact the overall cost-effectiveness of a system.

1.3 METHODOLOGY

In preparing this report, EPA collected available information on sensor technologies for remedial projects performed at Superfund sites, federal/military sites, and other sites. EPA attempted to compile information that was readily available and current for each project as of Summer/Fall 2004, however, in some cases, EPA was not able to confirm the available information. Some case studies include information provided primarily by the technology vendor, with limited input from a regulatory authority. In addition, for many of the projects, there were gaps in the types of information available (e.g., for some sites, performance data were not available, or there was a limited amount of data that independently evaluated sensor performance). This report is not a comprehensive review of all available sensor technologies or vendors.

2.0 OVERVIEW OF SENSORY SYSTEMS

Sensory systems used for automation, characterization, and monitoring can consist of a number of different components, including mechanical sensors, electronics, analytical (chemical) sensors, control systems, telemetry systems, and software. These components may be used alone or together to form relatively simple or highly complex systems.

Mechanical sensors by definition contain moving parts. For instance, turbine flow meters contain turbines that rotate as water flows through a pipe. Flow rate is measured by counting the number of revolutions per minute. When coupled with electronic transmitters, flow meters can form sensory systems that are able to measure and communicate flow data to a control unit or display. Other examples of mechanical sensors include floats (used in tank float switches) and pressure gauges.

Electronic sensors are electrically powered and can measure a variety of parameters such as pressure, specific gravity, the presence of liquid (water level meters and interface probes), pH, temperature, and conductivity.

Analytical sensors are typically used to measure chemical parameters such as contaminant concentrations. Some examples of analytical sensors include pH probes, and optical sensors used for colorimetric measurement

Control systems that work in conjunction with sensors include programmable logic controllers (PLC) and other electronic microprocessor devices. Control systems are able to receive sensory inputs, process information, and trigger specific actions.

Telemetry systems facilitate system control or data acquisition from remote locations. They can be radio or telephone based. Radio-based systems use radiofrequency communication devices to send and receive information. Telephone-based systems use modems to send and receive information through telephone lines.

2.1 CHARACTERIZATION OR MONITORING

Sensors used in characterization are typically used to measure environmental parameters. For example, a membrane interface probe may be used to detect and locate subsurface contamination; an electrochemical probe may be used to measure ground water parameters such as pH; and a thermometer may be used to measure sample temperature. Sensors in monitoring are typically used to measure both environmental and systemic parameters. For example, an anemometer may be used to measure wind velocity at a site; a water-level sensor may be used to measure long term fluctuations in ground water elevation; and a flow meter may be used to monitor flow through a pipe.

2.2 AUTOMATION

Automation systems use sensory devices to measure parameters necessary for proper system operation. Some examples of these parameters are water levels in wells and tanks, temperature, pressure drop, flow rate, and effluent concentration. These parameters are then used by microprocessor devices such as PLCs to make operational decisions including starting up or shutting down components of the remediation system.

Additional Sources of Information about Sensor Technologies

Field Analytic Technologies Encyclopedia (FATE) – an online encyclopedia intended to provide information about technologies that can be used in the field to characterize contaminated media, monitor the progress of remedial efforts, and in some cases, perform confirmation sampling and analysis for site close out. FATE includes information on several types of fiber optic chemical sensors. *http://fate.clu-in.org/index.htm*

Measurement and Monitoring Technologies for the 21st Century (21 M2) – through this initiative, EPA's Office of Solid Waste and Emergency Response (OSWER) will identify and deploy promising measurement and monitoring technologies in response to waste management and site cleanup program needs by matching existing and emerging technologies with OSWER program and client needs. Current projects include open path monitoring and sampling for contaminated sediments, as well as a summary of available literature on measurement and monitoring technologies. *http://www.cluin.org/programs/21m2/*

Remediation and Characterization Technology Database (EPA REACHIT) – an online database with powerful search options for information on treatment and characterization technologies, plus updated information from remediation projects undertaken by EPA. The database includes the following information for characterization technologies (as of March 2004): 158 technology vendors, 241 technologies, and 186 vendor source sites. *http://www.epareachit.org*

EPA's "A Review of Emerging Sensor Technologies for Facilitating Long-Term Ground Water Monitoring of Volatile Organic Compounds" – This report summarizes the status of emerging sensor technologies for facilitating long-term ground water monitoring for volatile organic compounds (VOCs). It also describes a number of factors, including regulatory acceptance and cost-effectiveness, that influence the applicability of these technologies. *http://www.clu-in.org/s.focus/c/pub/i/1040/*

Superfund Innovative Technology Evaluation (SITE) Program – established by EPA to aid engineers, scientists and other remediation professionals in the efficient monitoring, characterization and remediation of hazardous wastes. In this program, technologies are field-tested to assess performance. Cost and performance data are then presented in technology evaluation reports. *http://www.epa.gov/ORD/SITE/*

3.0 EXAMPLES OF REMEDIATION SITES THAT HAVE USED SENSOR TECHNOLOGIES

Table 1 identifies seven case studies on sensor technologies that illustrate their use in site characterization, monitoring, and process automation. The sites discussed in these case studies used the following types of technologies:

3.1 SITE CHARACTERIZATION

- Membrane Interface Probe – for contaminant concentrations
- Geophysical surveys – for evaluation of hydrocarbon contamination

3.2 MONITORING

- Capacitance probe – for soil moisture content
- VECTOR technology – for ground water flow velocity
- Burge System – for sampling and analysis

3.3 AUTOMATION

- Ozone analyzers and SCADA with PLC – for ground water pump and treat operation
- SCADA with PLC – for ground water pump and treat operation

Five of the seven case studies present characterization and monitoring sensor technologies; the other two (Moffett Federal Airfield, and Sprague Road Superfund Site) discuss sensor-dependent automation technologies. The technologies discussed in this report are commercially available, and have had at least one full-scale implementation. Projects for which case studies were completed were selected based on information in available databases and Internet resources, such as EPA's Clu-In Web site (*www.cluin.org*), and discussions with remediation project managers (RPMs), staff of both EPA Headquarters and Regional Offices, project managers from other Federal, state, and local government agencies, consultants, and vendors.

Each case study includes site background information, an overview of the sensor technology used and the goal for using the technology, a brief summary of remedial efforts at the site, information about the implementation of the sensor technology, and lessons learned. In addition, each case study presents cost data for the specific sensor technology. Where actual cost data are not available, estimated information is provided. Conclusions in the case studies are not limited to site-specific details. In most cases, conclusions include site-specific information and general information about the technology that might benefit potential users. References used in preparation of each case study are provided at the end of the case study.

TABLE 1. SELECTED CASE STUDIES ON SENSOR TECHNOLOGIES						
Site Name	**Technology Employed**	**Time Period of Use**	**Media of Concern**	**Contaminants**	**Goal for Use of Technology**	**Comments**
Sol Lynn/ Industrial Transformer Superfund Site, Houston, Texas	Membrane Interface Probe	January – June 2001	Ground water	TCE and its degradation products	Delineate ground water contamination and screen locations requiring further characterization.	MIP technology was used to identify highly contaminated regions in soil and ground water, as well as delineate the extent of the contaminant plumes in the various water-bearing zones.
Hotel Pier Site, Pearl Harbor, Hawaii	Geophysical survey techniques – 2D-Recon and 3D EOL	Not provided	Soil and ground water	Hydrocarbon contamination	Characterize areas of hydrocarbon contamination and assist in evaluation of remedial alternatives.	Electromagnetic surveys characterized hydrocarbon contamination based on the concept that soils contaminated with hydrocarbons feature higher resistivity than clean soils.
Badger Army Ammunition Plant, WI (Sub-Site BAAP-06-Deterrent Burning Ground)	Capacitance probe (for soil moisture content)	2004 – ongoing	Soil	Munitions based compounds	Measure soil moisture levels beneath a cap, to assess potential for leaching contaminants to GW at 100-110 ft bgs.	A nutrient infiltration gallery encouraged biological degradation of residual contamination beneath the cap. The capacitance probes served as sentinels against inadvertent flooding of the remediation zone that could potentially contaminate the ground water almost 100 feet bgs.

TABLE 1. SELECTED CASE STUDIES ON SENSOR TECHNOLOGIES						
Site Name	**Technology Employed**	**Time Period of Use**	**Media of Concern**	**Contaminants**	**Goal for Use of Technology**	**Comments**
China Lake Naval Weapons Station, CA velocity)	VECTOR technology (for ground water flow	1999 – ongoing (data through September 2004)	Ground water	Not provided	Monitor GW flow along southern property boundary, with potential for transport to nearby municipal well fields.	Each velocity sensor interfaces with an above-ground datalogger that records sensory data at a predetermined interval. Downloaded data is fed into an accompanying computer program which translates measured data to ground water flow speed and direction.
Moffett Federal Airfield, CA (West-side Aquifers)	Ozone analyzers and Programmable Logic Controllers (PLCs) in a ground water pump and treat system	2001 – ongoing (data through September 2004)	Ground water	TCE	Automate pump and treat system and monitor ozone in aqueous and gaseous media.	The ozone monitors work in conjunction with the PLC to ensure that (1) the correct dosage of ozone is applied to the influent water, (2) the off gas treatment system is meeting the air emission standards, and (3) the ambient air meets occupational safety and health administration (OSHA) standards.
North Indian Bend Wash, AZ, and Nevada Test Sites, NV	Burge System – (optical sensor)	North Indian Bend Wash: Jan 2002 – July 2003	Ground water	TCE	Analyze TCE in influent and effluent of ground water treatment plant on a daily basis.	The TCE monitoring system was used to provide automated monitoring of influent and effluent from a ground water treatment system.
		Nevada Test Site: December 2003 and March 2004	Ground water	Cr-VI	Analyze Cr-VI in ground water (pilot test).	The Cr-VI monitoring system was used for sample acquisition and analysis of Cr-VI contaminated water in a pilot test. This system is currently in use at the Hanford site near Richland, Washington.

TABLE 1. SELECTED CASE STUDIES ON SENSOR TECHNOLOGIES						
Site Name	**Technology Employed**	**Time Period of Use**	**Media of Concern**	**Contaminants**	**Goal for Use of Technology**	**Comments**
Sprague Road Superfund Site, TX	PLC and SCADA	2003 – ongoing	Ground water	Cr-VI	Automation of pump and treat system.	PLCs used to control valves and pumps. They interface with field sensors and interpret real-time sensory data to make system-control decisions (e.g., turn pump on or shut valve). The PLCs communicate through a wireless network and interface with desktop computers that serve as data loggers, continuously recording system operation data such as flow rates and totalized flow.

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Vendor Web Sites

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- Ametech, Inc. at *http://www.drexelbrook.com/*
- Analytical Measurements, Inc. at *http://www.anyliticalmeasurements.com*
- Bowles Corporation, Inc. at *http://www.bowles-corp.com/cet.htm*
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- Geophysical Survey Systems, Inc. at *http://www.geophysical.com/SIR20.htm*
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